Spec w/Amendments

COLD SPRAY APPARATUS HAVING POWDER PREHEATING DEVICE

BACKGROUND

Field of the Invention

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The present invention relates to a cold spray apparatus having a powder preheating device. ~~In~~ more particularly, the present invention relates to a cold spray apparatus having a powder preheating device, capable of obtaining a high deposition rate and an excellent coating layer under the same spray processing conditions by preheating coating powder before ~~a~~ the coating process.

Prior art

A thermal spray coating method is widely used to coat material ~~to~~ on a substrate. In the thermal spray coating method, a substrate that is a parent material is roughened by a blasting process and is coated by a mechanical bonding. That is, a powder is melted by several heat sources, such as electric arc and plasma, and then is sprayed on the substrate at high velocity. In this manner, the powder is coated on the substrate.

Such a thermal spray coating method can coat almost all kinds of material. Also, substrate temperature is increased slightly and a relatively thick coating is possible at a short time. For these reasons, the thermal spray coating method has been widely used in many industrial fields.

However, an original structure of the coating powder may be changed due to the melting of the coating material. Specifically, in the case of special structures like a nano or amorphous structure, material is melted even if raw material has nano or amorphous structure. Thus, after the coating, the resultant structure can hardly hold the original nano or amorphous structure.

When a material such as nano-structured WC-Co is sprayed at high velocity, a large area of the powder is exposed to the heat source and therefore WC is easily decomposed into a vulnerable carbide such as W_2C, W_3Co_3C or W_6Co_6C. Thus, the

thermal spray coating method has a disadvantage that can hardly obtain an excellent coating layer.

In order to solve the problems of the thermal spray coating method, a cold spray technique capable of coating powders at a low temperature has been developed. In the cold spray technique, powder particles having a size of about 1-50 μm are accelerated to a velocity of 300-1200 m/sec, which exceeds a threshold velocity at which a coating material can be coated on a substrate, by using high pressure gases, such as nitrogen, helium and air. The particles strike the target surface, the kinetic energy of the particles is transformed into plastic deformation of the particles, and a bond is formed between the particles and the target surface.

Since the cold spray technique coats the particles in solid state without melting them, it can solve somewhat the problems of the thermal spray coating method. In addition, since there is no residual tensile stress caused by solidification stress, a thick coating is possible. Therefore, the cold spray technique can be applied to "near net shaping" process.

The cold spray technique is disclosed in U.S. Pat. Nos. 6,365,222 B1, 6,491,208 B2, 6,139,913 and 6,283,386, and U.S. Pat. Pub. Nos. 2001/0042508 A1, 2002/0033135 A1, 6,502,767 B2, 2002/0073982 A1, 2002/0102360 A1, 6,444,259 B1, 2002/0182311 A1, 2002/0182313 A1, 2002/0182314 A1, etc.

U.S. Pat. No. 6,365,222 B1 discloses a process of repairing components using a cold spray technique, and U.S. Pat. No. 6,491,208 B2 discloses a process of repairing turbine blade. Also, U.S. Pat. Nos. 6,139,913 and 6,283,368 disclose a nozzle that can accelerate gas to high velocity in the range of 1000 m/sec or more. Those patents can be applied to powder particles having size of 50 μm or more. In addition, those patents PA discloses a cross-sectional area ratio of a main gas passage to an injection tube in a mixing chamber for mixing the accelerating gas and the coating particles.

U.S. Pat. Pub. Nos. 2001/0042508 A1 and 2002/0033135 A1 and U.S. Pat. No.

6,502,767 B2 disclose a method of easily disassembling a cold spray nozzle. A material for main feed tube and a maximum preheating temperature (700℃) are described in those publications and patent.

U.S. Pat. Pub. No. 2002/0073933 A1 discloses a method of applying a cold spray in coating a cylinder inner wall of a car engine block.

U.S. Pat. Pub. No. 2002/0102360 A1 and U.S. Pat. No. 6,444,259 B1 disclose a thermal barrier coating and an applying method thereof.

U.S. Pat. Pub. Nos. 2002/0182311 A1, 2002/0182313 A1 and 2002/0182314 A1 disclose a method of manufacturing electric machines using kinetic spray.

The above-described cold spray techniques are useful in various application fields, but have problems to be solved.

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First, there is a limit to usable materials because solid materials are used in the cold spray techniques. Specifically, ceramic is very difficult to use in the cold spray technique, while pure copper, nickel or aluminum is widely used because of ~~its high~~ their higher ductility.

Second, even the widely used materials must be sprayed at high velocity of more than threshold velocity so as to obtain an excellent coating characteristic. Otherwise, the yield may be degraded due to a low deposition rate.

Cermet materials, such as WC-Co, have high abrasive wear resistance and thus are widely used for industry. However, since the cermet materials have bad coating characteristic by cold spray, they are mainly used in the thermal spray coating technique. That is, the cermet materials are difficult to use in the cold spray technique.

The increase in the velocity of the accelerating gas can be achieved by increasing pressure of a gas supply unit. However, this method requires a large amount of gas so as to increase the gas pressure. Consequently, a large amount of gas is used so that economic efficiency gets worse.

In order to solve that problem, the accelerating gas is generally heated to about 400-600℃ so as to increase the gas velocity without increasing the pressure of the gas

supply unit in the cold spray apparatus. The method is effective in increasing the velocity of the accelerating gas because specific volume and pressure of gas can be increased and the adiabatic expansion effect at the nozzle can be obtained by this method.

However, if the method alone is used, it is difficult to obtain a satisfactory deposition rate, especially in the coating of cermet materials. Accordingly, the gas heater must heat the gas still ~~more~~ higher so as to increase gas temperature, resulting in an increase of the power consumption. In addition, the ~~a~~ lifetime of a tube in the gas heater is shortened and thus there is a limit in the increase of temperature.

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SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to substantially obviate one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a cold spray apparatus having a powder preheating device, capable of obtaining high deposition rate and excellent coating layer under the same spray processing conditions by preheating coating powder before a coating process.

To achieve the above object and other advantages of the present invention, a cold spray apparatus includes a gas controller for controlling gas supply amount of main gas and residual gas (gas that is not supplied as the main gas), a gas heater for heating the main gas supplied under the control of the gas controller, a powder feeder for receiving the residual gas under the control of the gas controller and supplying a coating powder together with the residual gas, a powder preheating device for preheating the coating powder supplied from the powder feeder, a mixing chamber for mixing the heated main gas with the preheated coating powder, a temperature controller for adjusting temperature by controlling the powder preheating device and the gas heater, and a nozzle for spraying the coating powder mixed in the mixing chamber.

The powder preheating device may include, a housing, a heater mounted on the housing to perform resistance heating, and a powder transfer pipe formed within the housing in a screw shape in order for fluid communication between the powder feeder and the mixing chamber, the powder transfer pipe transferring the coating powder.

The powder transfer pipe may be made of stainless steel.

According to the present invention, a cold spray apparatus having a powder preheating device can obtain high deposition rate and excellent coating layer under the same spray processing conditions by preheating coating powder before a coating process.

Also, the present invention can provide nano-structured super-high hardness WC-Co coating having high abrasive wear resistance and fracture toughness.

BRIEF DISCRIPTION OF THE DRAWINGS -

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FIG. 1 is a schematic view of a cold spray apparatus having a powder preheating device according to a preferred embodiment of the present invention;

FIG. 2 is a perspective view of the powder preheating device shown in FIG. 1;

FIG. 3 is a photograph showing a sectional structure of a coating layer, which is formed after an etching by the comparative example 4 of Table 5;

FIG. 4 is a photograph showing a sectional structure of a coating layer, which is formed after an etching by the inventive example 8 of Table 5;

FIG. 5 shows a result of an X-ray diffraction analysis on a coating layer, which is formed by the comparative example 4 of Table 5; and

FIG. 6 shows a result of an X-ray diffraction analysis on a coating layer, which is formed by the inventive example 8 of Table 5.

DETAILED DISCRIPTION OF ~~PREFERRED EMBODIMENTS~~ THE INVENTION

1 so as to observe the effects of the cold spray apparatus having the powder preheating device according to the present invention.

Table 1

Item	Condition	Remark
Powder	Nickel	99%, 10-45㎛
Coating substrate	SUS 304	5 mm thick
Distance between nozzle and substrate	15 mm	
Gas	Nitrogen	
Gas pressure	40 kg/㎠	
Gas temperature	700℃	
Feeding rate of powder	50 rpm (5 kg/hr)	
Moving speed of nozzle	10 mm/sec	
Number of coating pass	2	

The cold spray process was performed under the conditions of Table 1 while changing the powder preheating conditions as shown in Table 2 below.

Table 2

Classification	Powder preheating temperature (℃)	Deposition rate (%)	Coating thickness (mm)	Porosity (%)
Comparative example 1	None	16	0.51	5
Inventive example 1	150℃	32	1.01	2
Inventive example 2	250℃	59	1.83	2
Inventive example 3	400℃	89	2.77	2

The coating substrate used in Table 1 was roughened by a blasting process before the coating process.

As can be seen from Table 2, when only the powder preheating conditions are changed while all other conditions are equal, the deposition rate and the coating thickness are rapidly increased as the powder preheating temperature is increasing. Specifically, the

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comparative example 1 has the porosity of 5%, which is significantly ~~very~~ higher than those of the inventive examples. Thus, ~~the~~ in comparative example 1 ~~is~~ it was difficult to form a dense coating layer.

Embodiment 2: Review of Cold Spray Conditions of WC-Co Powder

Another embodiment of the cold spray apparatus having the powder preheating device according to the present invention is shown in Tables 3 and 4 below.

Table 3

Item	Inventive Examples 4, 5, 6	Inventive Example 7	Remark
Powder	WC-15%Co Particle size: 1-20 μm	WC-12%Co Particle size: 5-45 μm	nano- structure
Coating substrate	SUS 304	SUS 304	5 mm thick
Distance between nozzle and substrate	10 mm	15 mm	
Gas	Nitrogen	Helium	
Gas pressure	45 kg/cm^2	32 kg/cm^2	
Gas temperature	800℃	600℃	
Feeding rate of powder	30 rpm (3 kg/hr)	30 rpm(3 kg/hr)	
Moving speed of nozzle	10 mm/sec	10 mm/sec	
Number of coating pass	4	4	

Table 4

Classification	Powder preheating temperature (℃)	Coating thickness (mm)	Vickers hardness
Comparative example 2	None	0.1	1350
Inventive example 4	200	0.3	1470

Inventive example 5	300	0.35	1480
Inventive example 6	400	0.4	1550
Inventive example 7	500	0.9	2050

Table 3 shows the conditions when WC-12%Co and WC-15%Co was cold sprayed, and Table 4 shows the result when the cold spray process was performed under the conditions of Table 3, while changing the powder preheating temperature.

As can be seen from Table 4, the cold spray process of the comparative example 2 where no preheating process is performed is inferior to that of the inventive examples in view of both the coating thickness and the Vickers hardness.

In order to check the test results more thoroughly, the sections of the structures coated by the comparative example 2 and the inventive example 6 were observed by a microscope. Their results are shown in FIGs. 3 and 4. That is, FIG. 3 is a photograph showing the sectional structure of the coating layer, which is formed by the comparative example 2, and FIG. 4 is a photograph showing the sectional structure of the coating layer, which is formed by the inventive example 6. It can be seen that the structure of

PA FIG. 3 is less dense ~~not denser~~ than that of FIG. ~~Fig.~~ 4. Also, the structure of FIG. 4 maintains the nano-structure well. Accordingly, the coating layer of the present invention provides ~~can have the~~ excellent coating thickness and hardness. In addition, unlike the thermal spray coating method, the transformation of the nano-structure does not substantially ~~almost~~ occur.

Embodiment 3: Comparison of the Cold Spray Method with Thermal Spray Coating Method

In order to compare the cold spray method of the present invention with the conventional thermal spray coating method, a ~~the~~ test was performed under the conditions set forth in ~~of~~ Table 5 below. Other ~~condition to perform~~ cold spray coating conditions were the ~~is~~ same as ~~that~~ those of Table 3 according to the composition of WC-Co.

the inventive example, an X-ray diffraction analysis was performed on the coating layer. FIG. 5 shows a result of the X-ray diffraction analysis on the coating layer, which is formed by the comparative example 4, and FIG. 6 shows a result of the X-ray diffraction analysis on the coating layer, which is formed by the inventive example 8.

The difference can be obviously seen in FIGs. 5 and 6. That is, referring to FIG. 6, peak positions of WC and Co appear clearly but mid-phase cannot be checked. On the contrary, referring to FIG. 5, both peak of W_2C and Co transformed by the thermal spray and peak of WC contained in the powder reduced. Therefore, it can be seen that the hardness is reduced.

As described above, the effects of the cold spray apparatus having the powder preheating device and the cold spray method of WC-Co powder using the same can be confirmed.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

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~~INDUSTRIAL APPLICABILITY~~

The present invention ~~can provide the~~ provides a cold spray apparatus and method, that ~~can~~ solves the problem of the conventional thermal spray coating method in which the compound and structure of the particles in the conventional method are transformed so that it is difficult to form the desired coating layer. In addition, the cold spray apparatus and method of the present invention ~~can~~ effectively and economically forms the coating layer that can solve the problems of ~~the~~ poor porosity and deposition rate.